ITER: Progress & Challenges

Steps Forward for

Large International Science Collaborations

2009 Linear Collider Workshop of the Americas

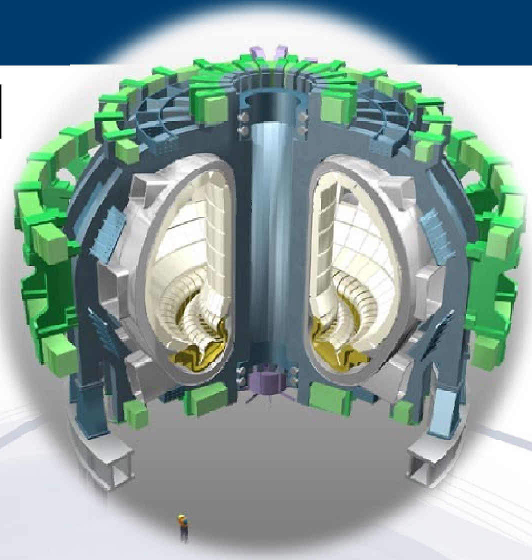
September 29, 2009

Carl Strawbridge, UT-Battelle, LLC

Views from an ITER Partner (US)

- ITER Design, Construction, Management & Organization
- Challenges in Technical Integration & System Engineering
- Challenges in Project Management: Schedules & Baselines
- Improving Planning for Large International Science Collaborations

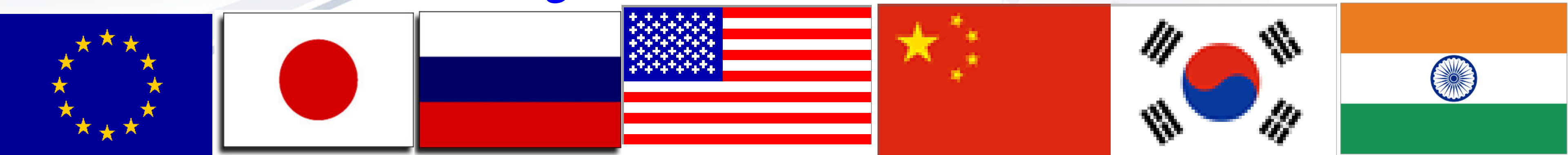
ITER: A Special Partnership



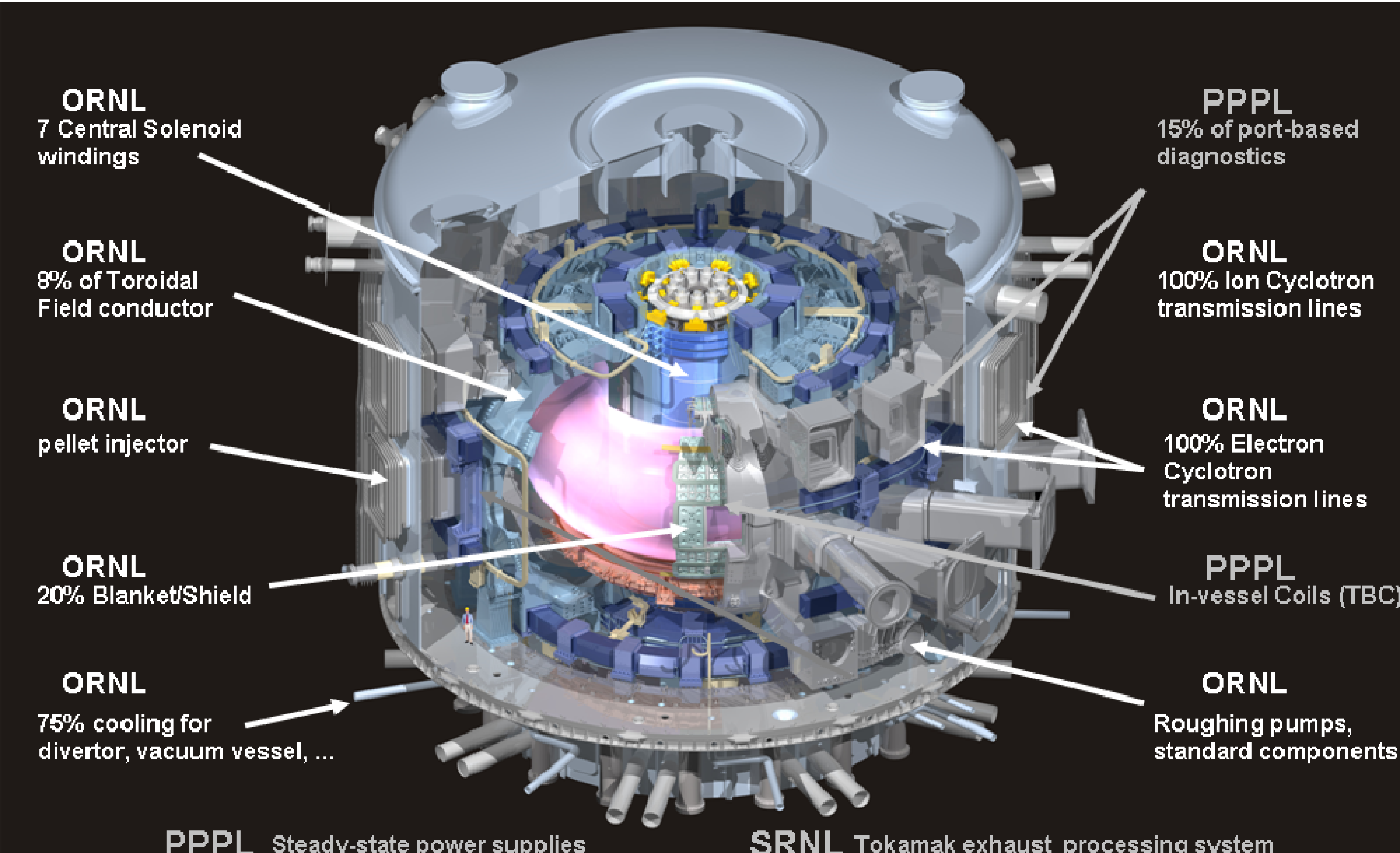
- **Addressing a global challenge and opportunity:**

ITER's Mission:
to Demonstrate the Scientific and Technological Feasibility of Fusion Energy

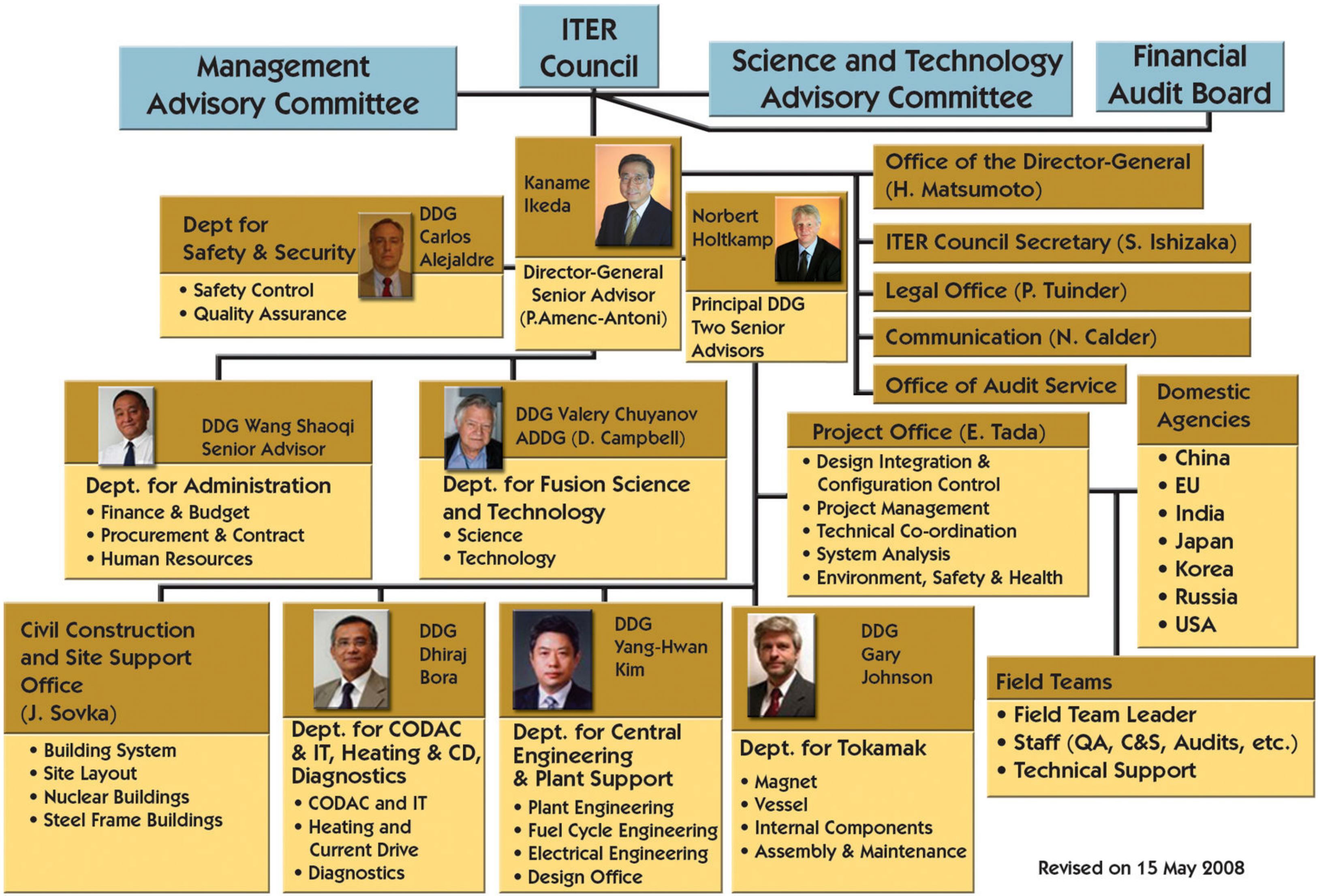
ITER's partnership:
a unique arrangement of nations jointly responsible for construction, operation, and decommissioning



U.S. ITER In-kind Contributions (9.09%)



ITER Organization: Some adjustments now approved



Revised on 15 May 2008

ITER Staff is growing to ~650 by the end of 2011

Professional staff	**274**
Directly Employed Staff (DES)	239
Secondment (SEC)	35
Support Staff	**158**
Directly Employed	119
Temporary Arrangement Staff	39
Total	**432**
Visiting Researcher	5

Professional Staff by Parties

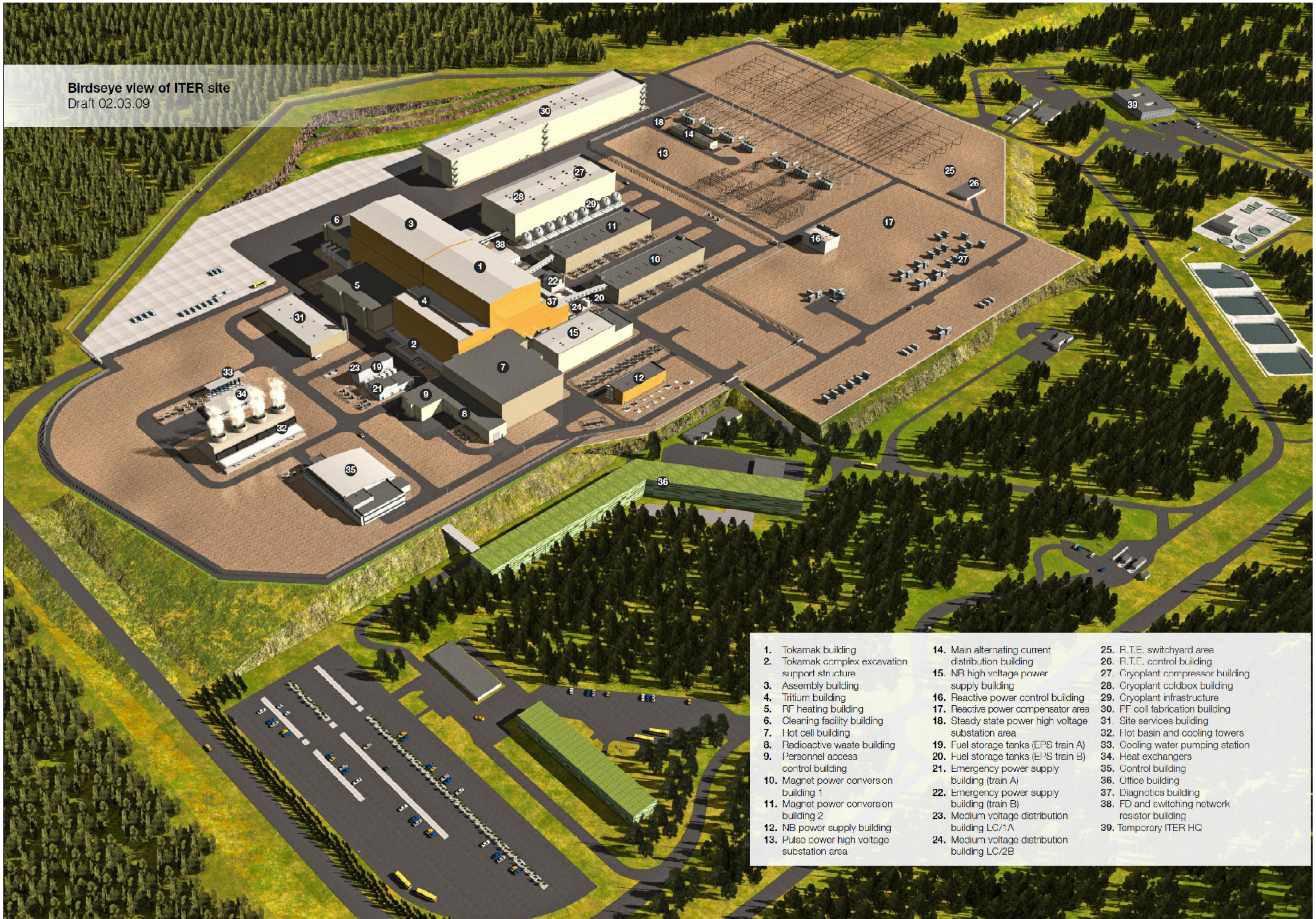
Category of Staff	European Union	India	Japan	China	Korea	Russian Federation	United States	Total
DES	130	14	23	15	19	21	17	**239**
SEC	30						5	**35**
Total	**160**	**14**	**23**	**15**	**19**	**21**	**22**	**274**
VRs	3	2						**5**
	58.4%	5.1%	8.4%	5.5%	6.9%	7.7%	8%	

ITER Near Term Objectives

- **ITER Council Approval of Integrated Baseline**
  - Member concurrence with Integrated Project Schedule
  - Member concurrence with added scope, budget and allocations among Members
  - Complete review of ITER Organization overall costs (non-in-kind)
- **Initiate site work (EU scope)**
- **DA-IO Agreement on critical-path procurements:**
  - Vacuum Vessel (EU, KO)
  - CS Magnets (US, JA)
  - PF Magnets (EU, RF, CN)

ITER Site is ready for excavation

Future ITER Site Build-out



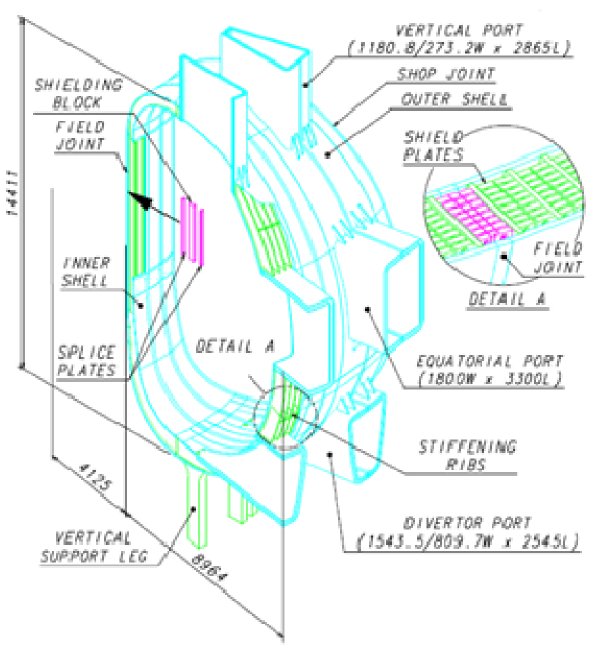
Challenges in Systems Engineering

- ***ITER Systems Engineering Management Plan provides a structure for managing and integrating ITER design***
  - **Addresses key SE processes and management practices**
    - **SE roles and responsibilities**
    - **Requirements analysis and management**
    - **Configuration management**
    - **Interface control**
    - **Design reviews and design verification**
    - **Engineering specialty integration (RAMI, part standardization, value engineering, constructibility, etc.)**
- ***A strong Systems Engineering approach is required by the Project Specification approved by ITER Council***
    - **ITER SEMP pending approval as part of baseline (lags component design and interface development)**

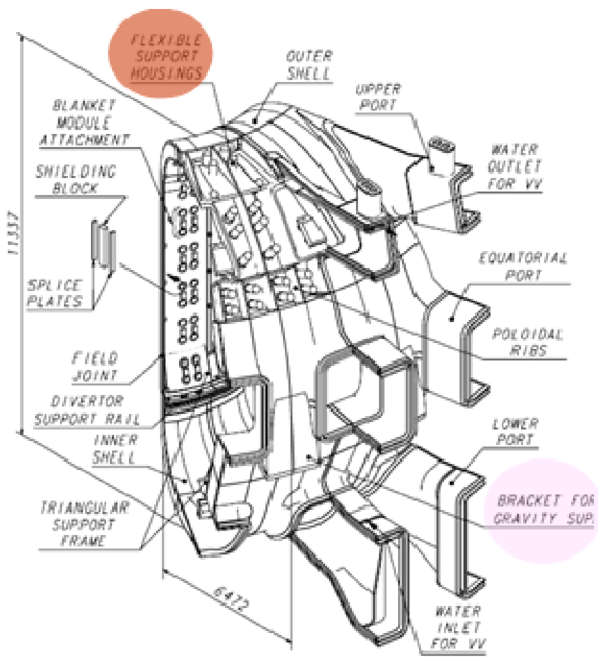
Integrated requirements + rigorous design reviews = top IO priorities

- Requirements reviews disclosed some major inconsistencies
  - e.g., no inclusion of coil current scenarios that define envelope for machine operation and heat loads on plasma facing components
- Design review procedure was developed with IO & DAs to:
  - Ensured participants reflect independence as well as expertise (needed to ensure ownership by IO and Members of results)
  - Track follow-up to issues where the documented design does not conform to documented, approved requirements
- Proved effective in identifying issues with the VV through the FDR in July 2008 and subsequent follow-on reviews
  - Procurement Arrangements were delayed, VV design was modified to ensure fabrication could proceed at reasonable risk

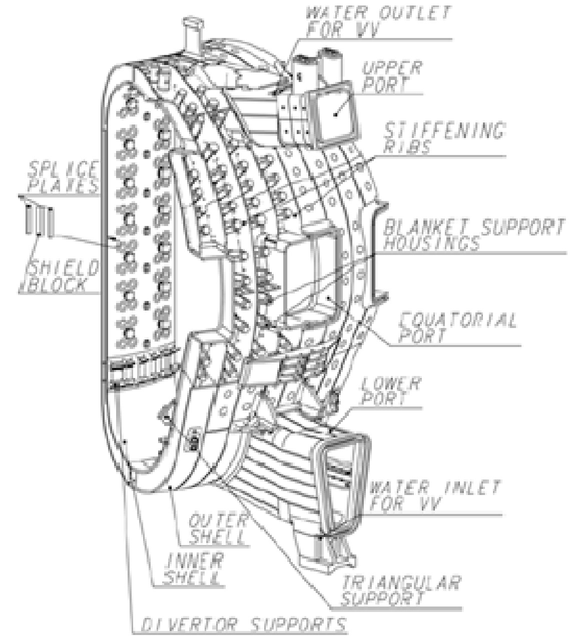
Vacuum Vessel design has evolved



1998 Baseline



July 2001 Baseline



Sept. 2004 Baseline

Size reduction
- H:14.4 m to 11.3 m
- W:8.9 m to 6.4 m

Add. of Flexible Support Housing

Reduction of lower ports
Relocation of VV support
Add. of local penetrations

(Included full scale prototype)

Ref: KO, B.C. Kim

2008 Vacuum Vessel design review: VV no longer met requirements – tech, cost, or schedule

Technical issues defied simple fixes

IO identified 5 primary issues:

- Electro-magnetic loads on Blanket supports too high
- Nuclear heating of TF coil too high: 23 kW vs. 14 kW limit
- Field joint design is too narrow: 120 mm vs. 240 mm tested
- In-vessel coils (ELM + VS) design is very complex *90 in-vessel joints, ceramic insulation in water bath, etc.*
- Blanket manifold is extremely complex, very little space

What impeded progress?

- **Requirements not fully documented**

  Late approval of SRD for VV before the final design review, higher level PR not yet in place

- **Few periodic, formal design reviews comparing the design to the requirements**

  Final Design Review was the first rigorous, formal, comprehensive review under the IO procedure

- **Minimal/dated industrial involvement in post EDA re-design of VV (broad concern—EDA was a long time ago and the design has evolved)**

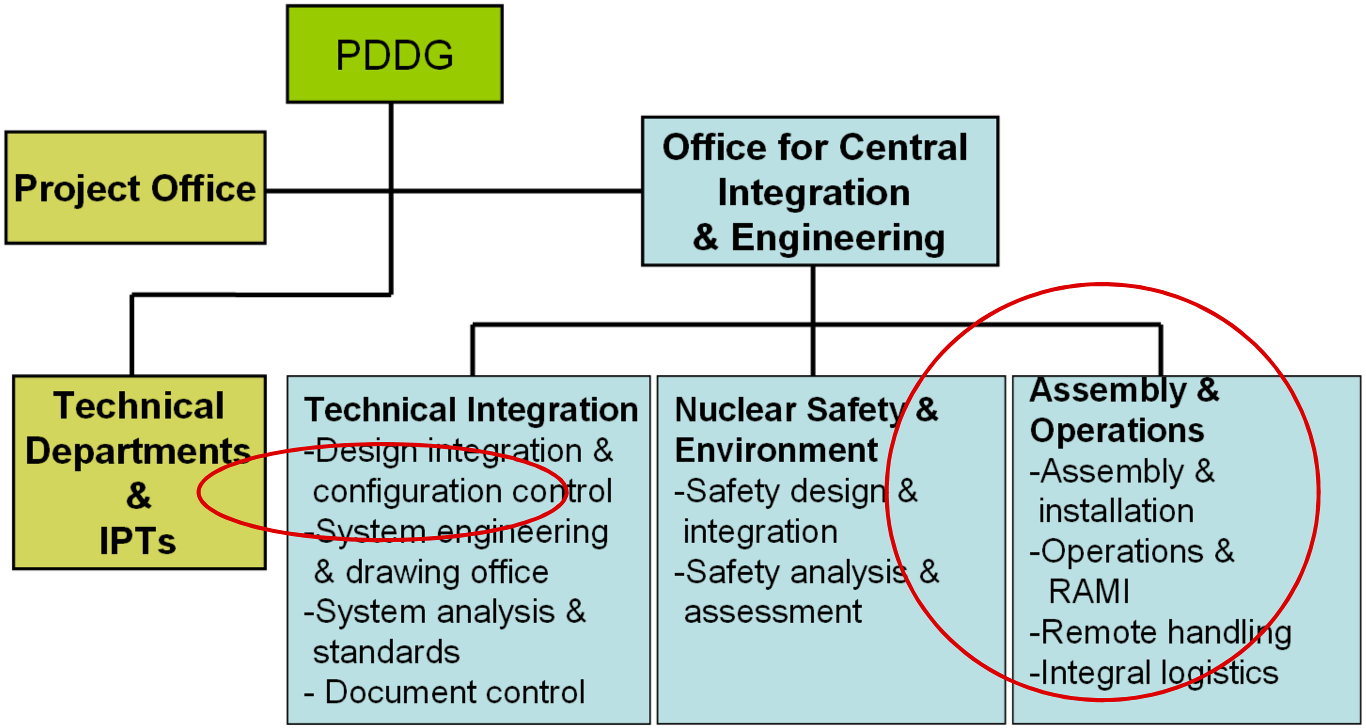
- **Schedule pressure on problem solving**

Better is the enemy of good enough,

……but only if it is good enough

IO re-organizing to improve technical integration focus

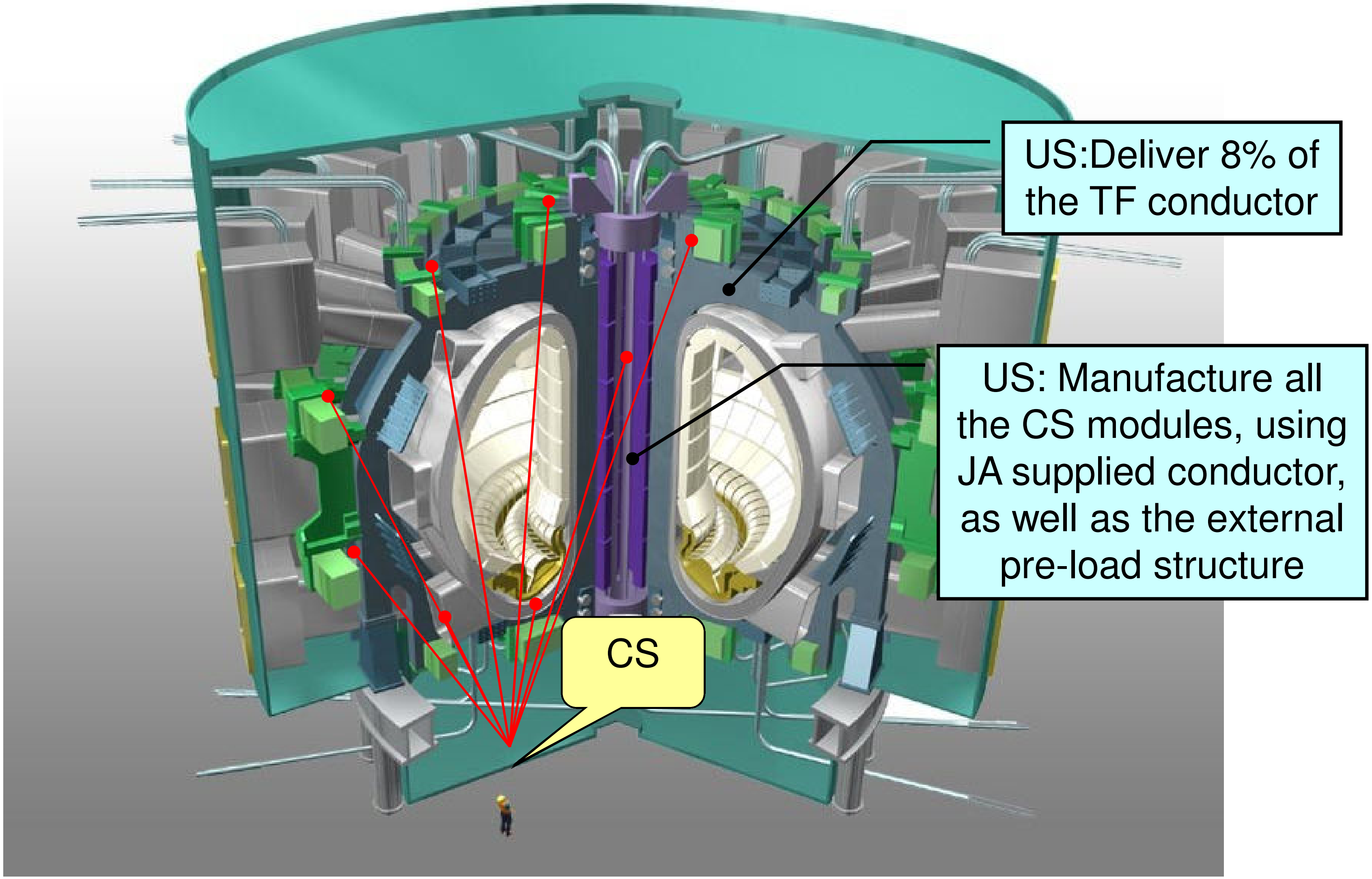
Improvement – Central Integration & Engineering



Improvement:

Office for Central Integration & Engineering to be responsible for technical Integration/engineering and work with the IPT staff for system engineering:
- Provide systems and tools for integration and engineering
- Monitor and control the technical baseline

ITER Magnet Systems

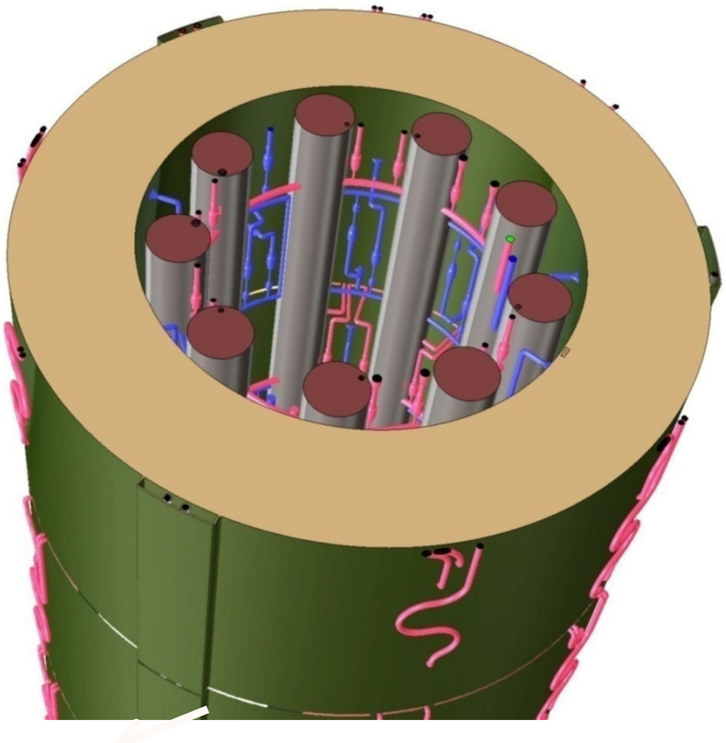


US,JA & IO Must Together Manage Risks for CS Modules and Structure

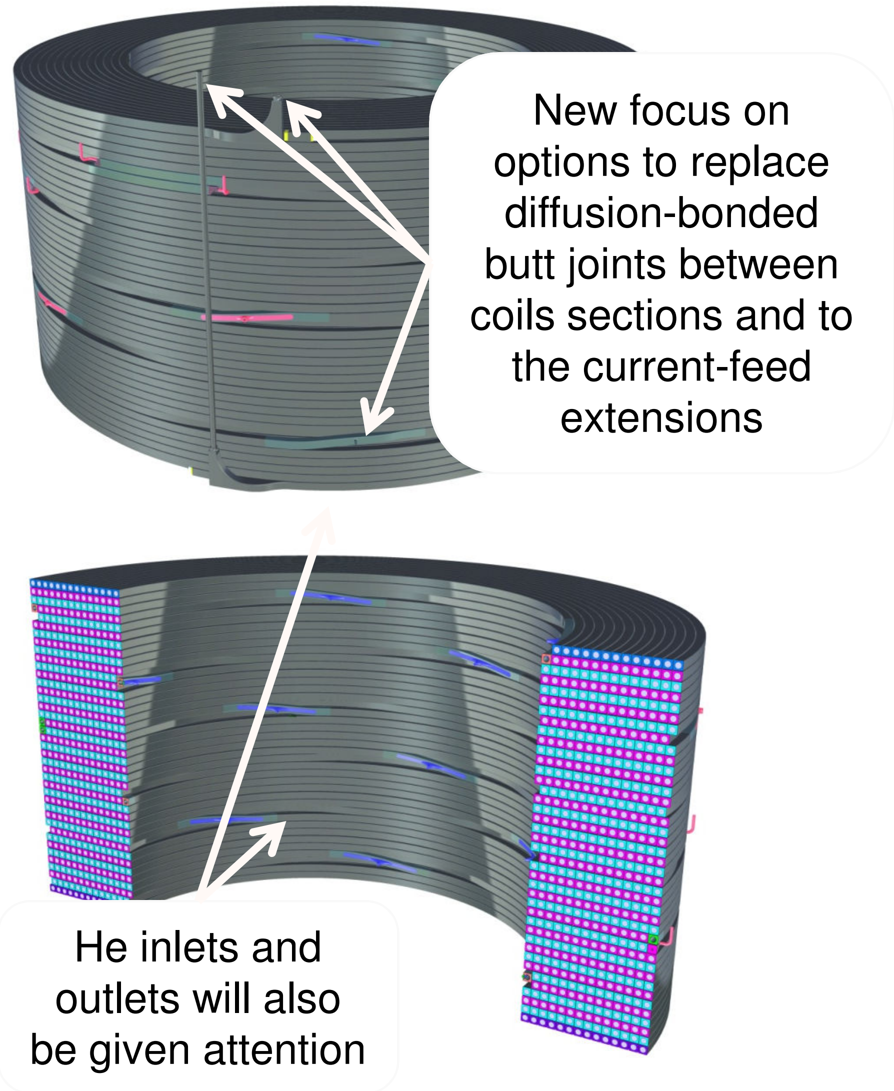
Risk	Mitigating Actions (recent advances)
Obtaining quantity & quality of conductor for mockups & manufacture	Quality: CSMC insert test + Prototype module Quantity: Sufficient quantity to be provided by JA at additional cost
Insulation system is not capable (29 kV test)	Confirm insulation system design by fabrication and test of increasingly larger scale models: Small stack, Full-height sector, Prototype module
Superconductor has inadequate temperature margin $T_{CS} \geq 5.2$ K, 4.5 K inlet	CSMC insert test + Prototype module
Jacket alloy not clearly established (JK2LB or 316 LN)	316 LN chosen via PCR 185
US and IO working independently on different designs for external structure	PCR submitted for study of US design, decision in December PCR to change PA from build-to-print to func spec
Conductor jacket has inadequate fatigue life (need 0.75 mm^2 flaw, not 4 mm^2	Collaborate with JA on improved NDE and grind both ID and outside of butt weld

CS Coil Modules supply: 6 plus spare

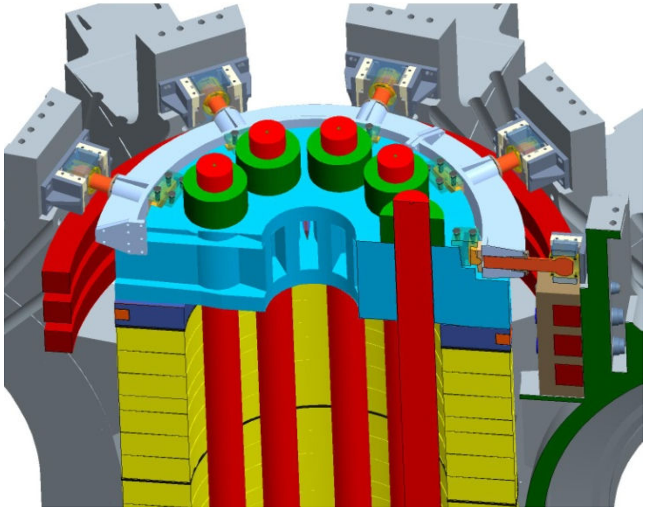
- New Conductor conduit material:
  Was: JK2LB, Now: 316LN-mod.

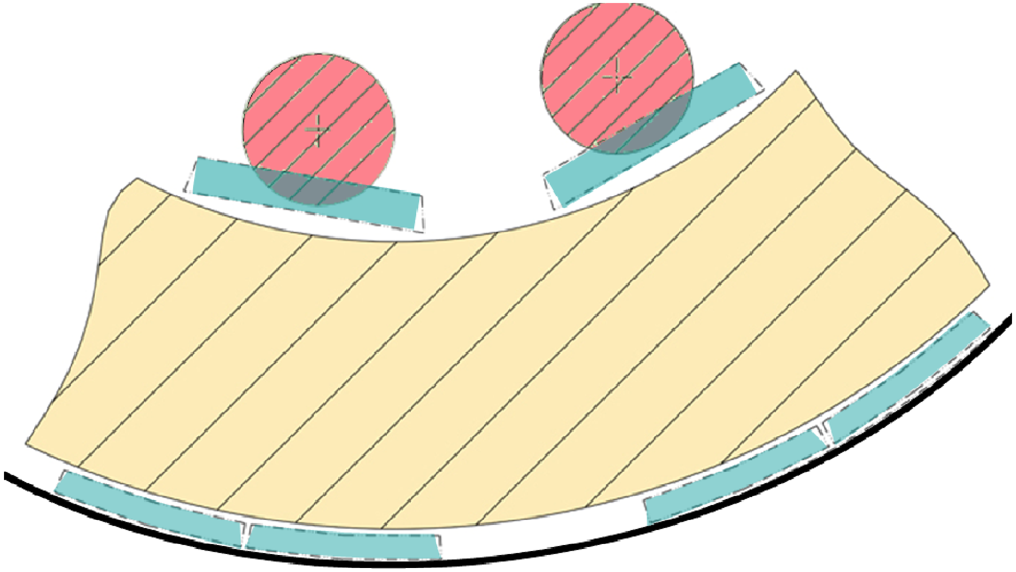


- Still activity to settle the designs of critical components



Reference and US Proposed Alternate Preload Structure





Ref. design

Tie plates

-No room

-Hard to preload

Alt. design

Tie Rods

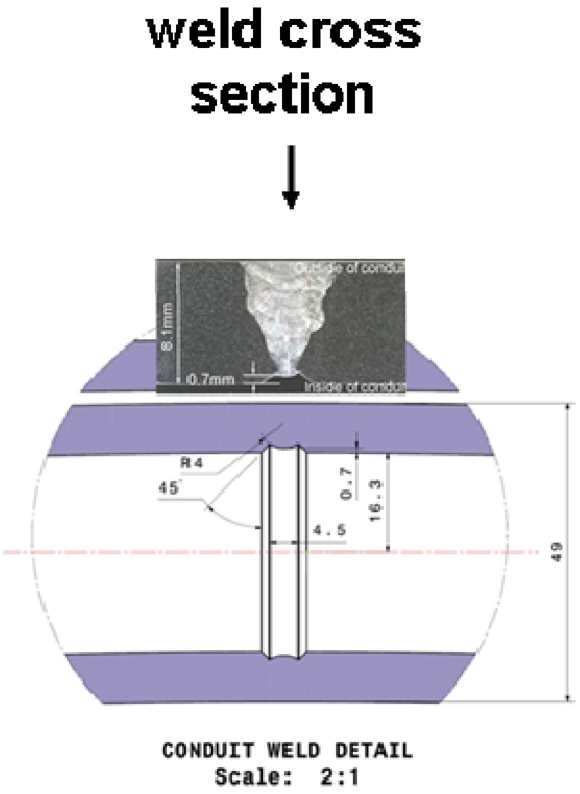
- All structure in bore

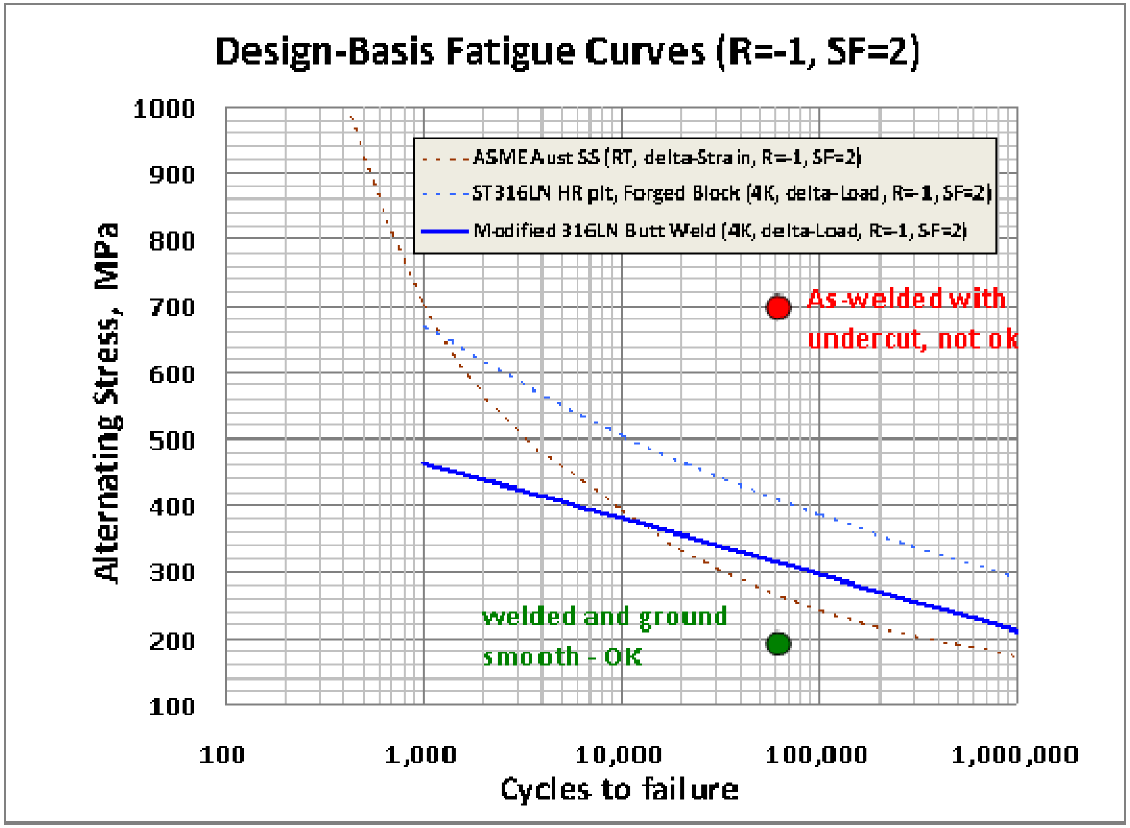
- Conventional tensioning of rods

- frees up OD for clearance, leads, helium lines

Near-term Risk w/ CS Conductor Joints – Conductor Fatigue Life

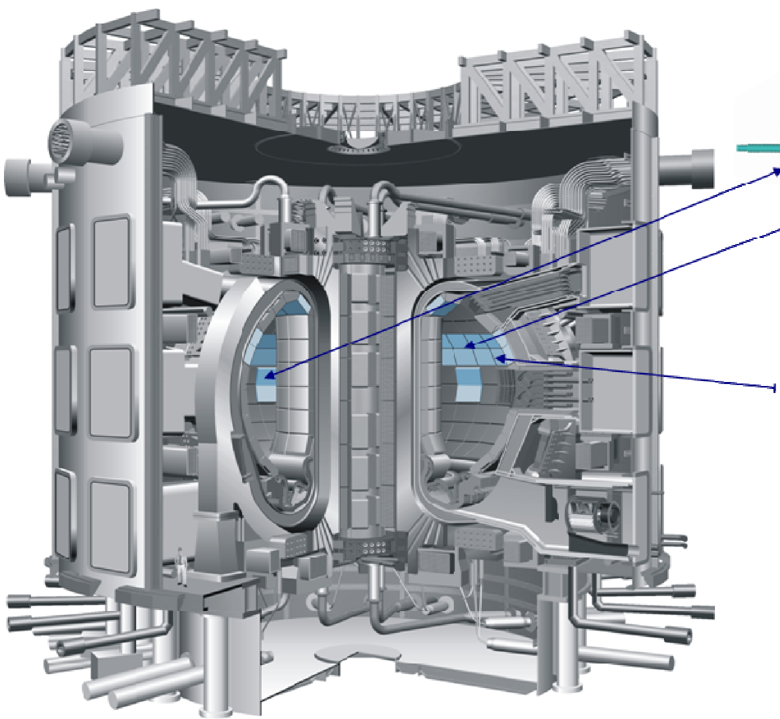
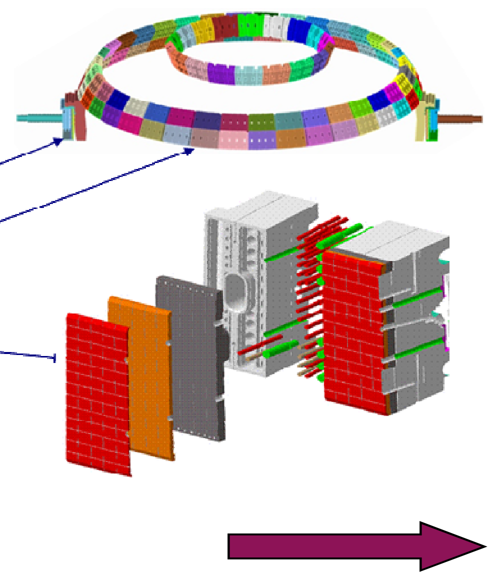
- Current butt weld design creates high stress concentration
- Proposed option for weld to be “full” and ground flush



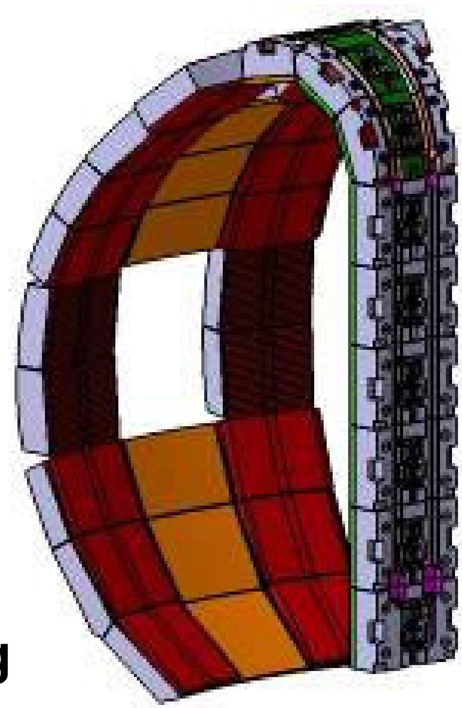


Blanket Modules: Original US Scope is changing

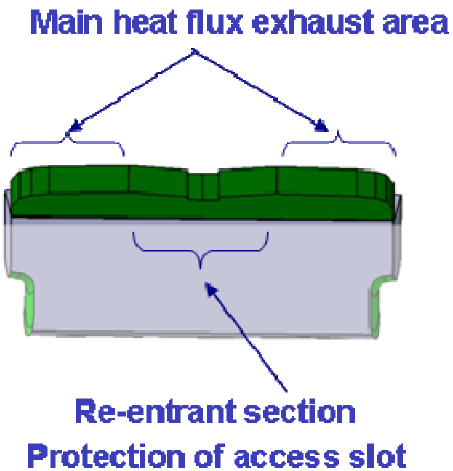
- **Blanket Modules – 20% allocation**
  - **3 toroidal rows, #7, 12 and 13**
  - **90 blanket modules consisting of:**
    - **90 shield module subassemblies, 90 first wall (FW) subassemblies, 6 spare FW subassemblies**
- **Port Limiters – 100% allocation** ***(likely swapped for port plug blanket modules)***

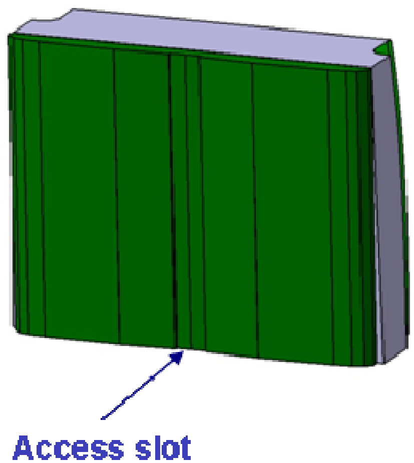



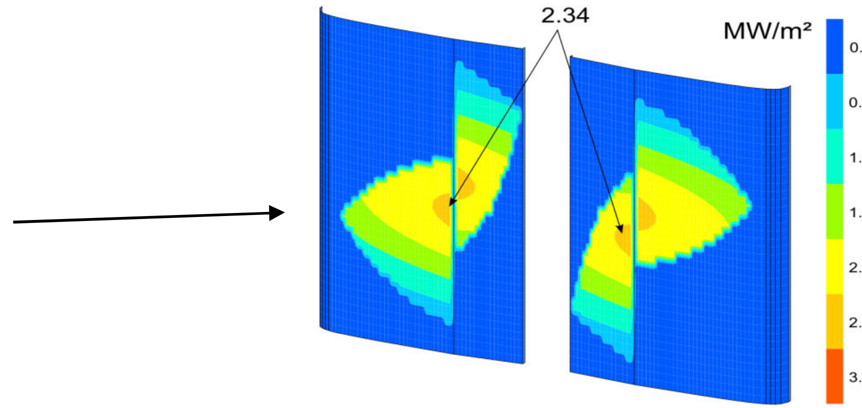
Config. is evolving



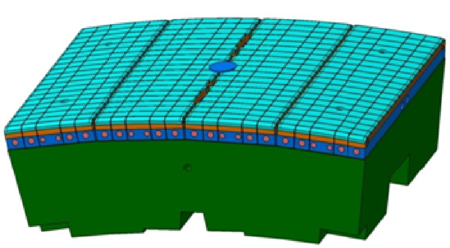
Blanket redesigned for updated thermal loads



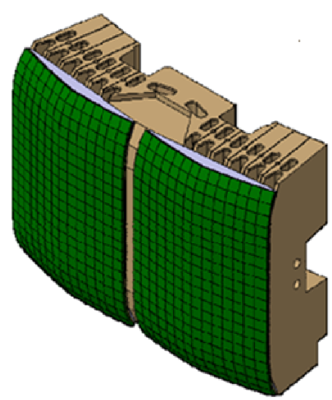




2001 Module Design



Present Module Concept

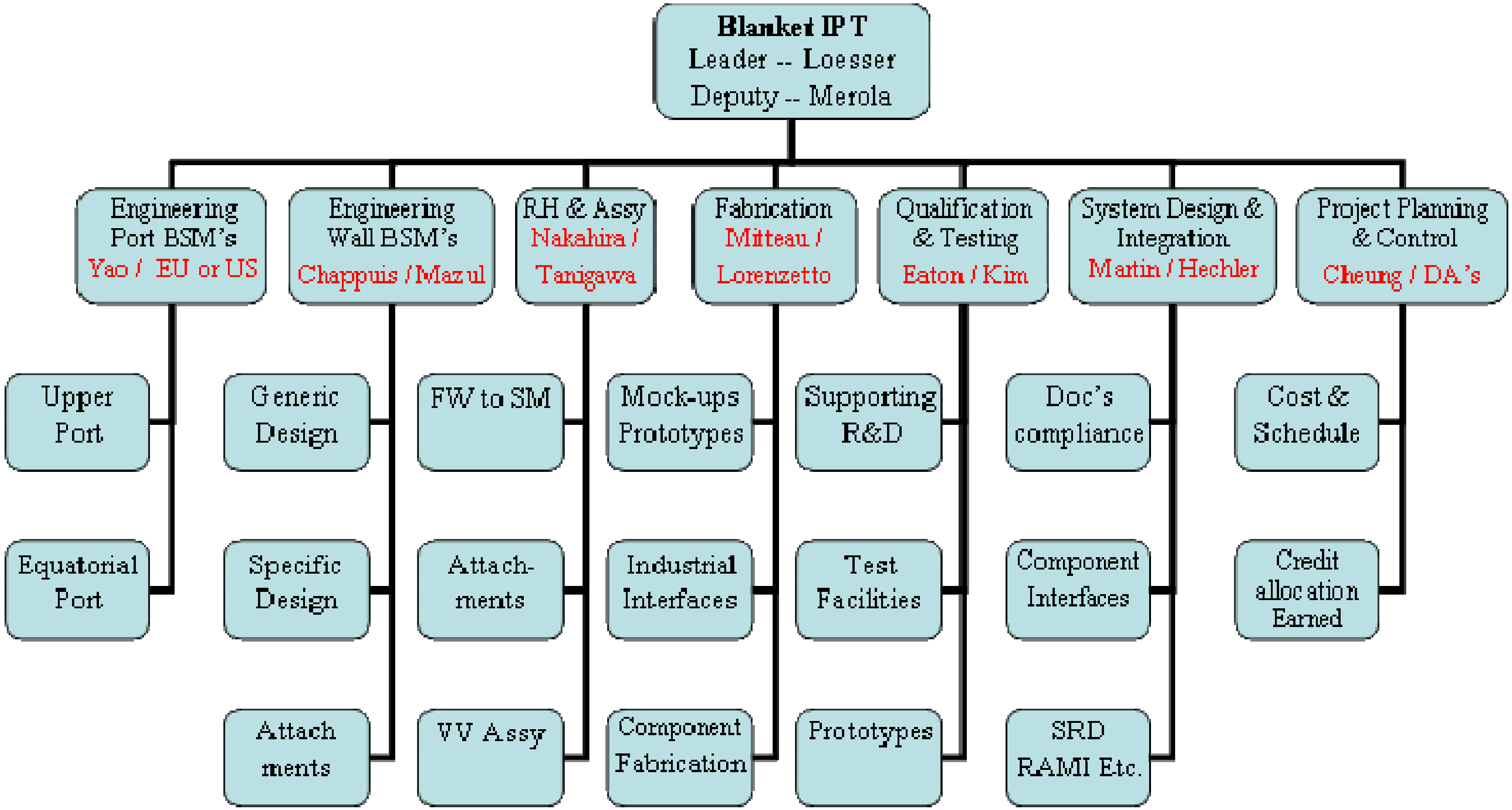


	1.57 MW/m²	Base heat flux
	2.34 MW/m²	With 5 mm local misalignment
x 1.45	3.38MW/m²	Long wave misalignment
x 1.07	3.61MW/m²	Full ripple
x 1.15	4.16 MW/m²	Faceting with 50 mm tiles
+ 0.5	*4.65 MW/m²*	Radiation, charge exchange

~ 10 x original heat load

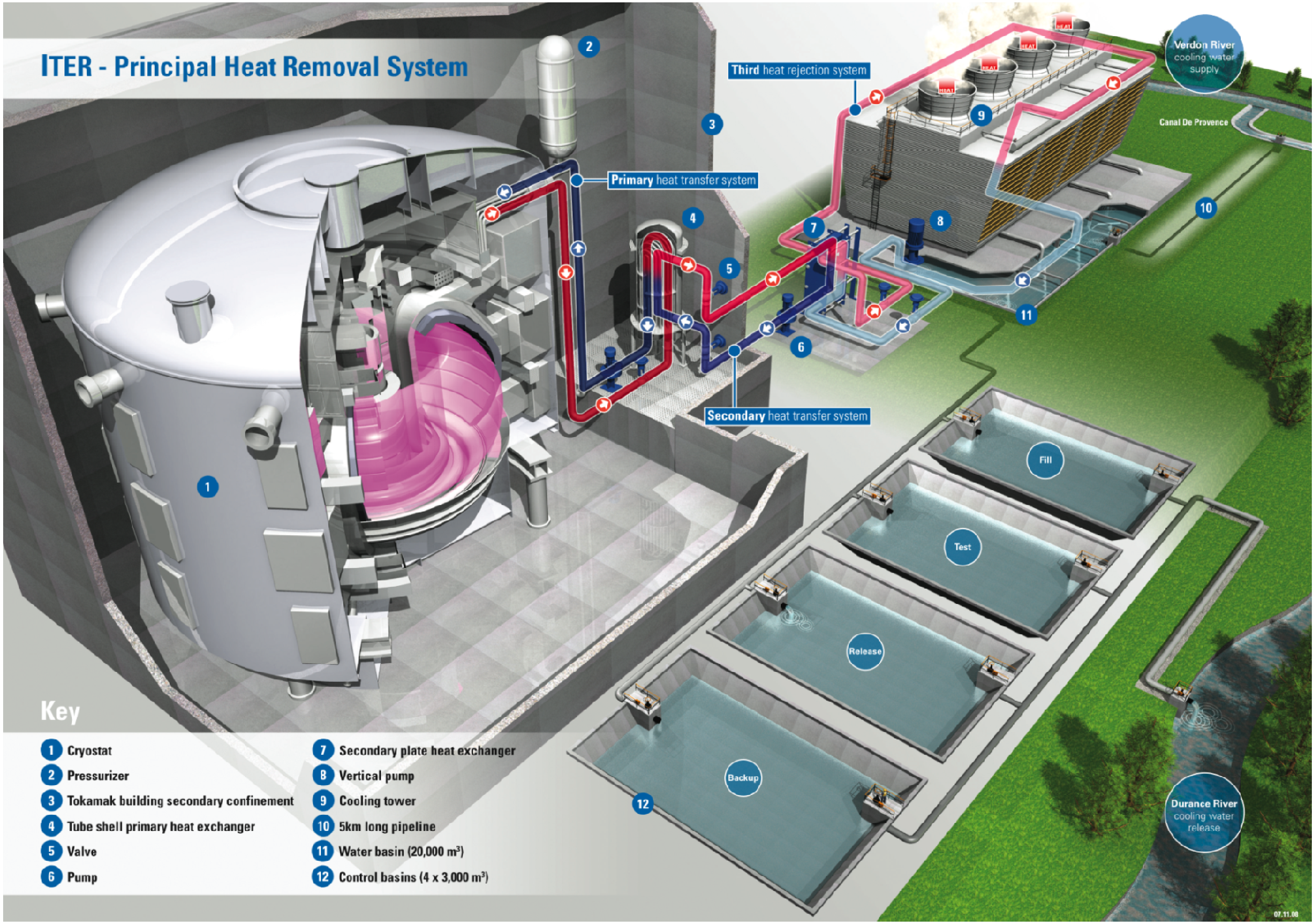
Blanket Integrated Product Team Formed to Coordinate 6 Contributing Members

- IPTs provide major subassembly integration
- A number of such teams now exist to support responsible IO DDGs

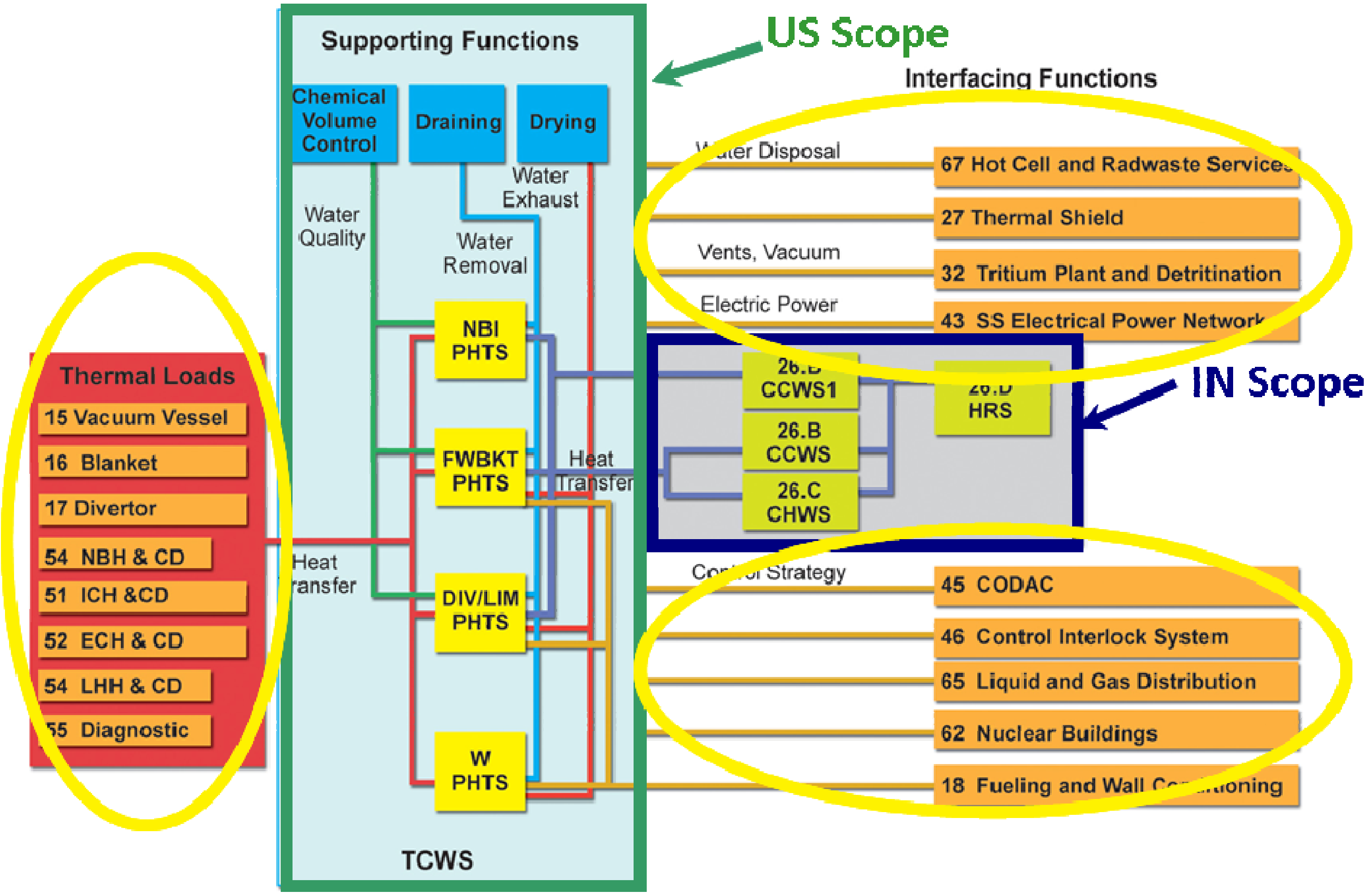


Tokamak Cooling Water System (US & IN)

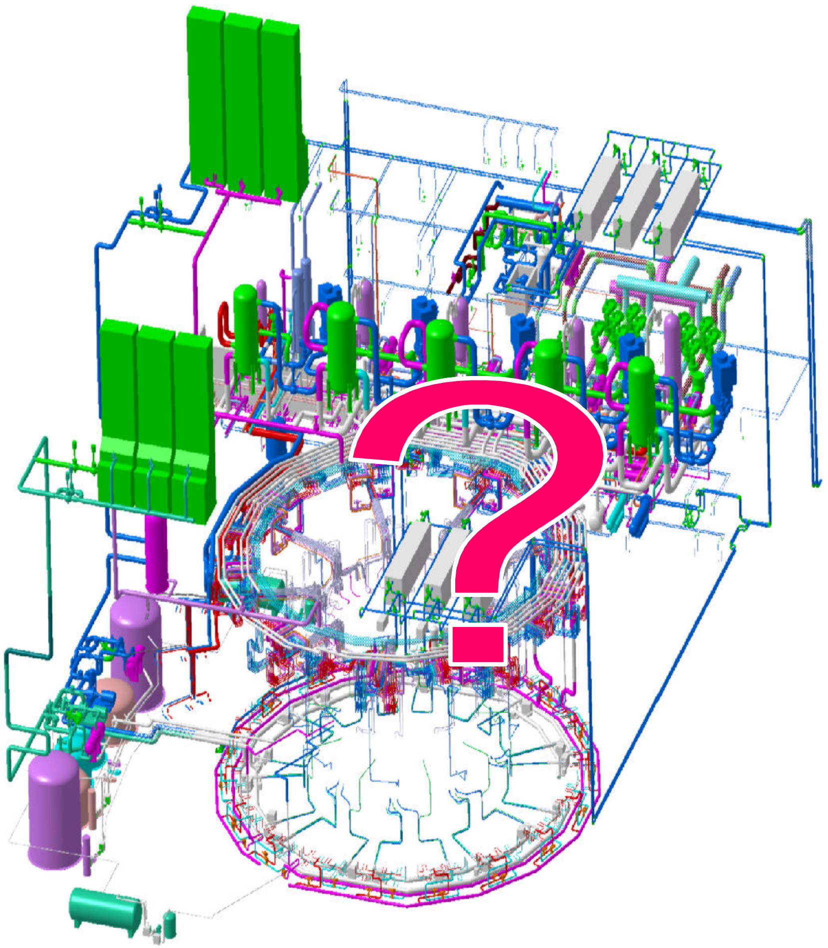
Project1:Layout 1 7/11/08 19:47 Page 1



Physical TCWS scope: well defined
Interface with India: well coordinated



TCWS has undergone extensive redesign to meet client system needs



Design Change Requests

- Uncertain requirements
- Growth in scope

Requirements:

- Safety-critical system
- Questionable reliability/availability
- Incomplete design basis calculations, documents
- Incomplete PFD and P&IDs

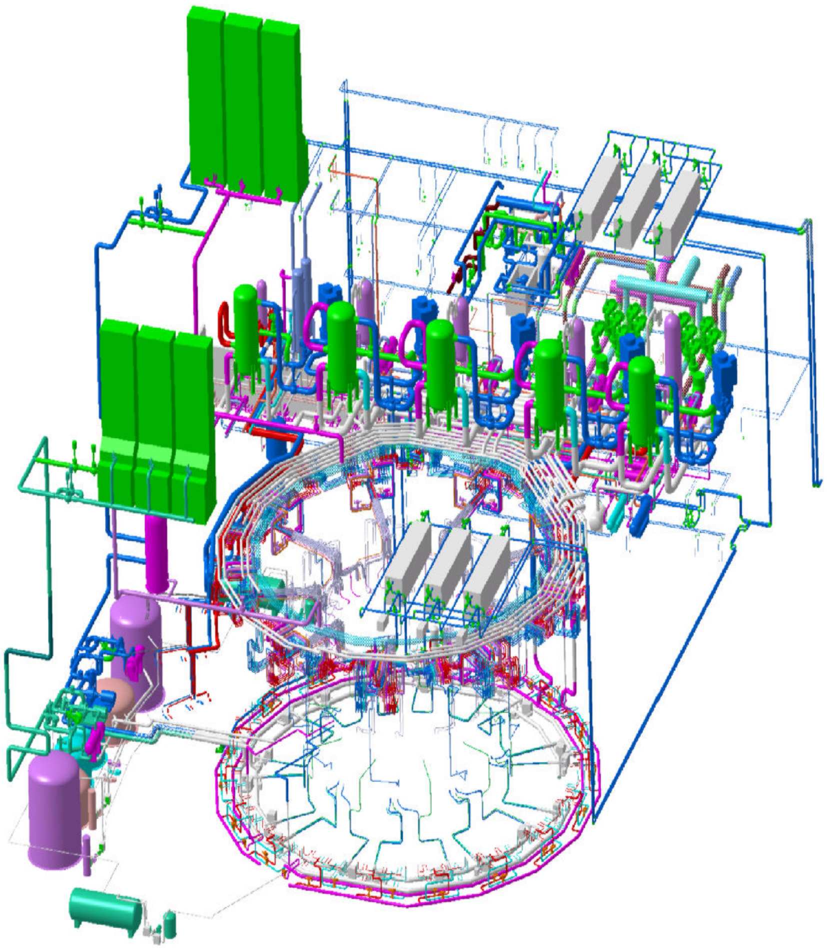
Fabrication:

- Difficult to fabricate components

Redesign

- Incomplete physical layout of piping
- Design integration tools unworkable

TCWS Risks Managed with Systems Approach



Design Change Requests

- Proposing design and requirements improvements (eliminate 2 independent VV loops, air heat exchangers, etc.)

Requirements

- Completed RAMI analysis
- Modeled and completed design basis calculations, documents
- Developed PFDs

Fabrication

- Industry fabrication improvements

Redesign

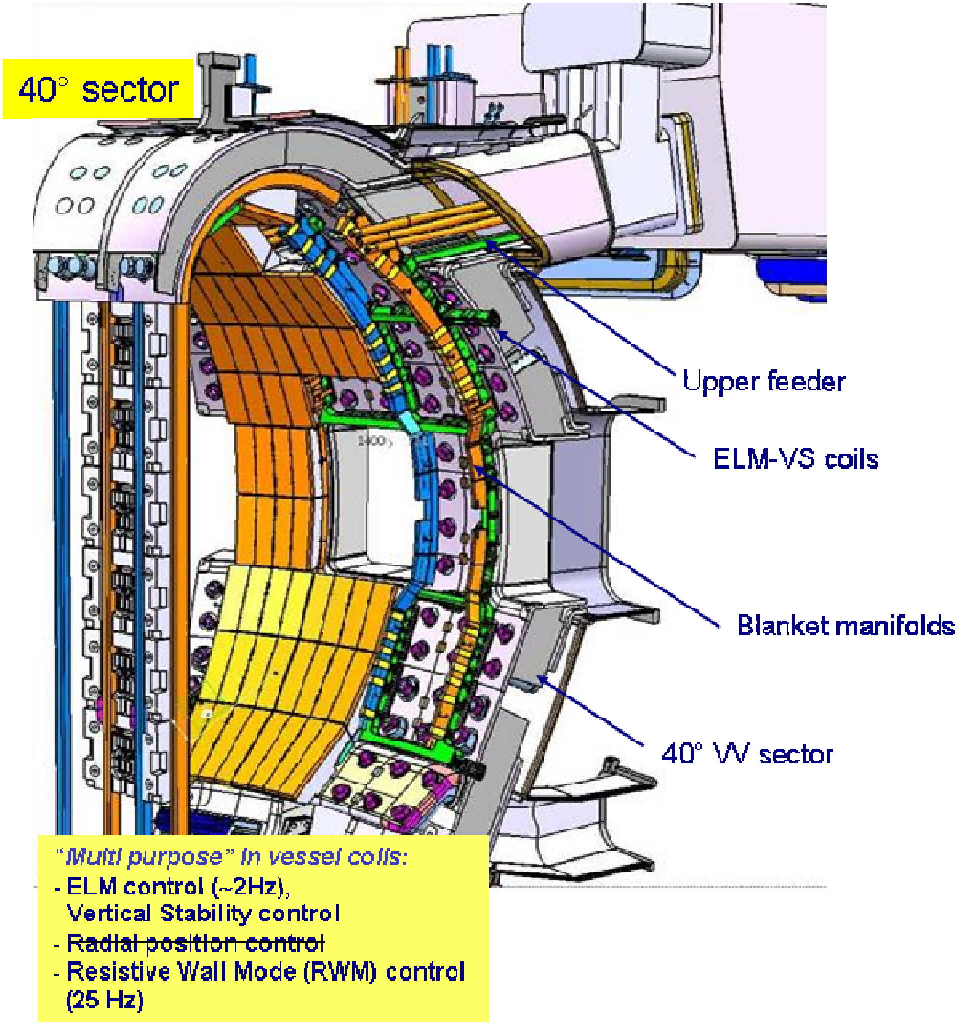
- Conceptual Design Review
- Proceed with workable CATIA solution
- Maximize industry involvement

In–vessel (ELM and VS) coils

- **Proposed scope added as a result of STAC recommendations to control ELMs (resulting from plasma instabilities that create first wall high heat loads) and provide vertical stabilization**

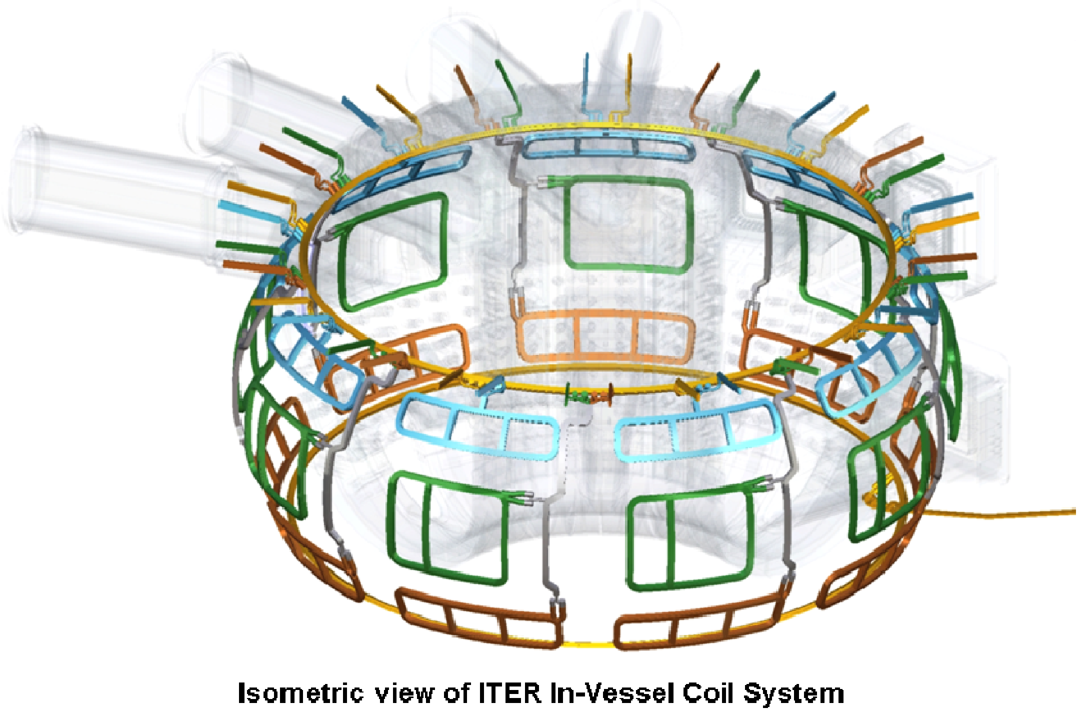
- **Initially attempted integration of coils *without changing VV dimensions—too hard***

- **Necessary R&D plan is extensive**

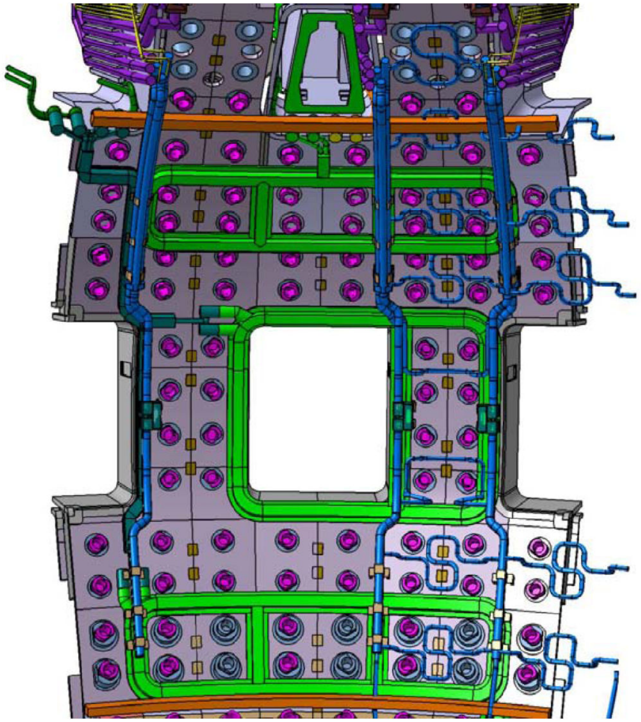


In-vessel coils are complex

- 27 ELM coils, 94 kA-t each with separate power supplies
- VS ring coils top and bottom, 240 kA-t each
- Integration with VV and blankets, electrical insulation, remote maintenance, and cost are major issues



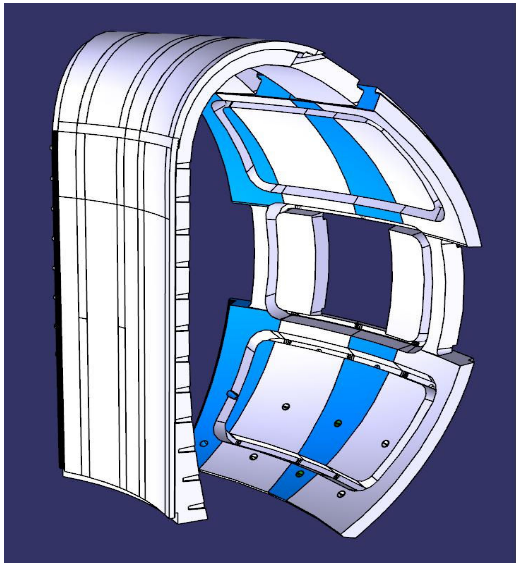
Isometric view of all in-vessel coils and feeders



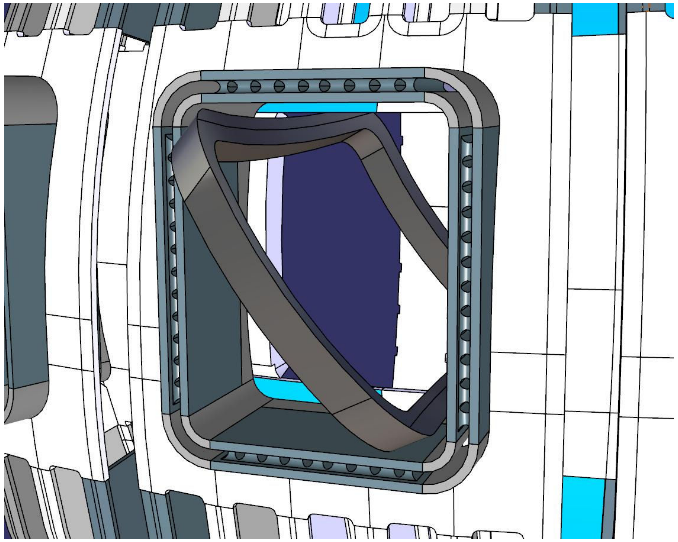
View of one sector from plasma side

Path forward for In-Vessel Coils

- U.S. (PPPL lead) to continue design and R&D of reference design according to Task Agreement
- ITER asked U.S. to develop cost estimate
- U.S. also investigating alternative coil options
  - Put ELM coils in front of shield, behind first wall
  - Separate the VS coils from ELM coils



Cutouts for ELM coils



Coil through port

Challenges in Project Management: the ITER Integrated Project Schedule

- **In development for 2 years, issues have included**:
  - Completing essential design development
  - Integrating DA components to support IO installation and assembly schedule
  - Completing associated budgets and DA resource profiles to understand full commitments of Members (independent cost review follow-up in October)

- **At November ITER Council, Members will be asked to commit (with resources/funding) to the key milestones and their deliverables in the IPS**
  - Council requesting evaluation of IO " schedule confidence"
  - DAs evaluating now (challenging due extensive ties of thousands of activities

- **Phased installation approach reduces technical risk, flattens resource peak requirements**
  - 1st plasma in 2018
  - 2 installation phases (2019/2020 and 2022)

Establishment of IO baseline necessary for establishment of U.S. baseline

- ITER will certainly be a challenge for the DOE 413 process— US needs tailored approach for int'l work
- CD-0 (approve Mission Need) – approved July 2005
- CD-1 (approve Cost/Schedule Range) – approved January 2008 ($1.45B-$2.2B, FY2014-2017)
- CD-2/CD-3 (establish performance baseline/authorize execution)
  - If IO baselines accepted in November 2009, forecast for USDA CD-2/CD-3 is Q4 2010
    - CD-2 strategy may need to be phased, but only 5 of 12 US/IO Procurement Arrangements will be approved by 2010…

Extending Project Management to New, Complex Challenges

- Emergence of large-scale international collaborations to develop ‘big science’ research facilities introduces new challenges to current PM methods and practices:
  - State-of-the-art R&D and technology
  - Exceedingly high energies, temperatures, radiological concerns, special or uncharacterized materials, plasma diagnostics and control
  - Fast-tracking/overlapping phases of R&D with engineering design and construction
  - Multiple partners with make-or-break scope

Achieving Successful Outcomes w/LISPs

- Lessons learned, practical experience from large international science projects (LISPs) must be captured and introduced in a disciplined, accessible, timely way into planning cycle for future projects
  - Organizational/legal frameworks may differ
    - CERN model (LHC) vs Independent Legal Entity (ITER)
  - Different experience levels and limited sharing across scientific communities
    - Accelerator builders vs fusion modelers
    - Balance framework/procedures vs experience
  - One-off types of facilities (limited learning curves)

Achieving Successful Outcomes w/LISPs

- LHC, ALMA, ITER experiences should be used to improve success of ILC, SKA, etc.

  - What /how to capture?
  - Where to insert in the planning process?

ALMA

Atacama Large Millimeter / submillimeter Array

U.S. iter

LISPs vs. Conventional Projects: Differentiating Characteristics

- Worldwide participation
- Partner criteria
- Central organization governance
- Multisource funding
- Political risk in funding
- Social risk
- Local control
- Cross-country collaboration
- Coordinating in-kind contributions
- Large budgets
- Dependence upon scientific, technological breakthroughs

Central Organization Governance

- In conventional single-organization projects, governance structure is often centralized. Lines of authority and responsibility are reasonably clear
  - ‘Borderless’ organization should also be LISP goal
- Creating central organization for LISPs that meets partners’ interests and can exert effective governance is complex
  - Decisions requiring full consensus become harder as number of participants grows, which can practically affect schedule
  - Central organization must be integrator and leverage resources in contributors, including design
- Each participating country expects that its financial contribution and scientific expertise should ensure it a prominent role within the central organization
  - Defining “prominent” can be an issue
  - Management team can be politicized vs. best capable

Political realities will create a unique time constant (plan for it)

ITER examples:

- Dissolution of Soviet Union
- Gain/loss of partners: – US (1999) + US (2003) – Canada (2003) + China + South Korea (2003) + India (2005) + Kazhakstan (?)
- Government changes in several Members that created delays due to differing priorities
- US 2008 budget reductions; restored in 2009
- Global currency devaluations squeezing many budgets

Coordinating In-kind Contributions

- **Contributions may be 'in-kind' and/or cash or mix**
  - 'In-kind' describes systems, hardware, and components to be delivered by each partner (ITER is 90% in-kind)
  - Cash can fund staff, common site expenses, operations and hardware contributions
  - Pros, cons of each…settled in project implementing agreements
- **In-kind contributions increase systems integration challenge**
  - Partners must meet common design requirements and construction standards; all technical interfaces must be carefully defined and managed through design, fabrication, testing
  - Project technical complexity further exacerbates need

LISPs Affect Project Management

- Management structure and governance
- Work distribution among partners (interfaces!)
- Budget allocations (host, non-host)
- Family and education benefits, pay equity (attracting staff)
- Managing intellectual property rights
- Meeting national export control laws and regulations
- More….

ITER will matter!

- **ITER is a technical prototype for fusion energy…**
  - Central system integrator vs detailed designer
  - Member resources must be leveraged (industry)
  - Organization, requirements & procedures must be tailored to staff & community construction experience
- **ITER is a management experiment with international partnerships that will affect later collaborations…**
  - Effective project management methods must be defined early (pre-agreement) & accepted by participants

Back-up

U.S. ITER Domestic Agency Team

U.S. DEPARTMENT OF ENERGY

Office of Science

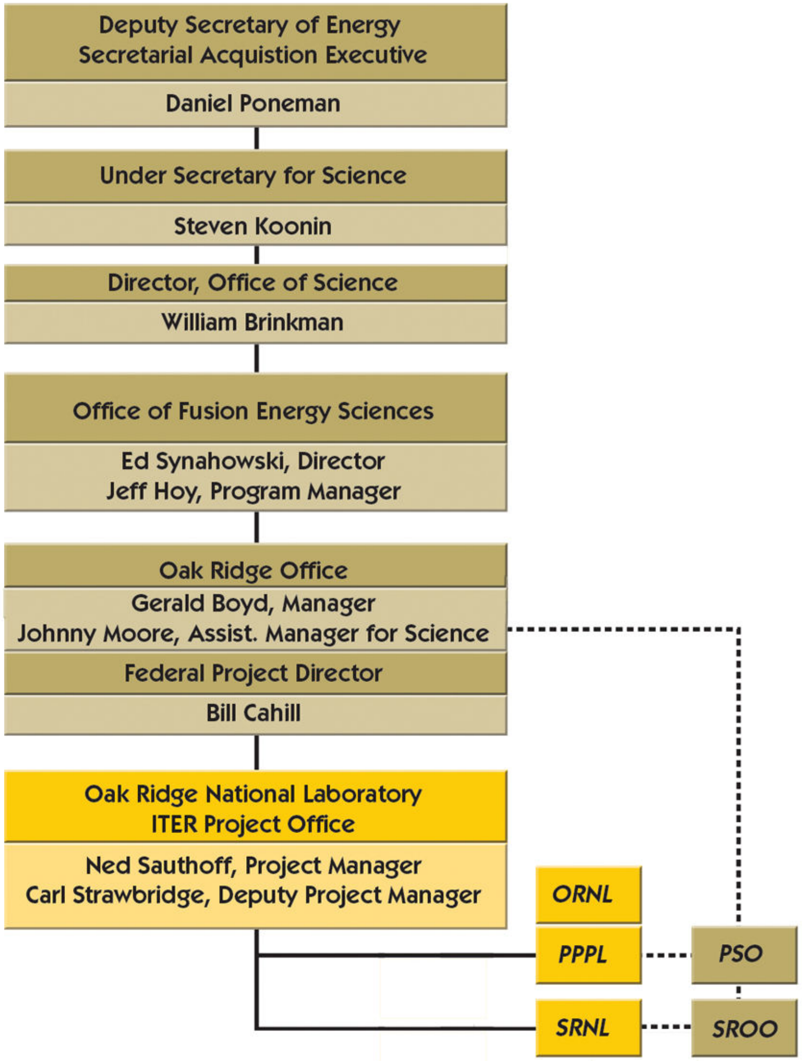
ORO	Oak Ridge Office
PSO	Princeton Site Office
ORNL	Oak Ridge National Laboratory
PPPL	Princeton Plasma Physics Laboratory
SRNL	Savannah River National Laboratory
SROO	Savannah River Operations Office

------ Line managment reporting relationship

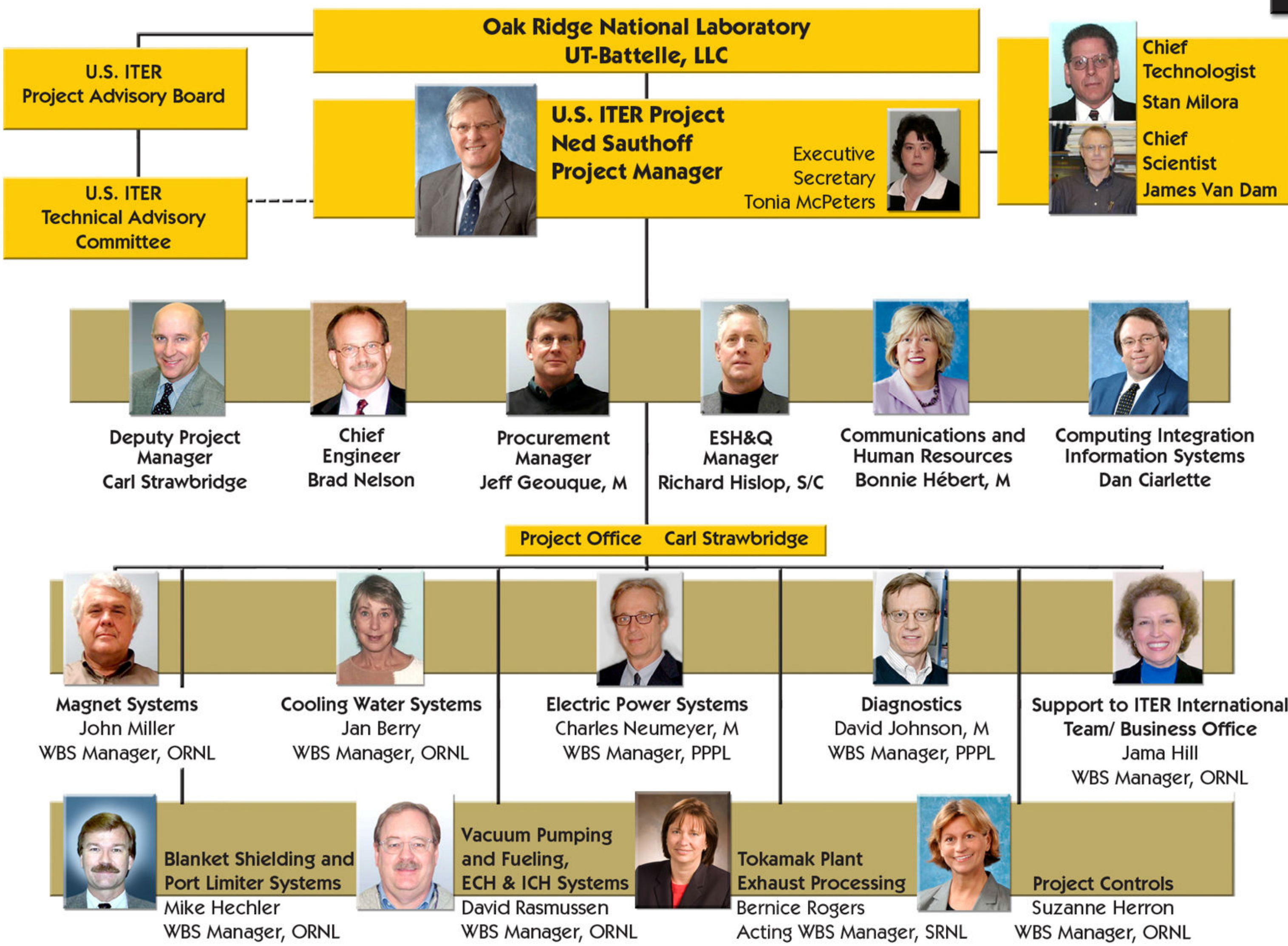
—— Coordination relationship

Department of Energy

Oak Ridge National Laboratory and Partners



U.S.ITER Project Office



US Staff at ITER & ORNL

ITER International Staffing (U.S.) (Direct hires and secondees)	
DDG/Sr. Scientific Officers	4
Tritium Group	2
Engineering	7
Cooling Water Systems	1
Vacuum Vessels	2
Diagnostics	1
Administrative	5
Monaco Fellowship	1
	23

USIPO Staffing (ORNL)	UT-Battelle	Contractors
Project Office	6	1
Blanket Shielding & Port Limiters	1	0
Cooling Water	7	1
Magnets	3	9
ESH&Q	1	1
Engineering	3	3
ICH, ECH, Vacuum Pumping	1	1
Project Controls	5	5
Business	6	0
Procurement	5	0
HR/Communications	4	1
	42	**22**
TOTAL	**64**	

Why Develop Separate Body of PM Knowledge for LISPs?

- Current PM standards do not deal adequately with LISP issues
- More LISPs but overall fewer than other types of projects that populate popular knowledge base
- Lessons and experienced staff tend not to be renewed and applied due to extended schedules and in specialist fields
- Size/scale have unique challenges (global procurements)
- Risk, uncertainty roll up to senior government level
- Political, economic consequences of failure
- Management risk rivals technical complexity